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Carter et al.

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(54) **COOLING TOWER WITH INDIRECT HEAT EXCHANGER**

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F28D 15/00 (2006.01)
F28F 3/00 (2006.01)
F28C 3/06 (2006.01)

(52) **U.S. Cl.**

CPC ***F28D 15/00*** (2013.01); ***B01F 3/04468*** (2013.01); ***F28F 3/005*** (2013.01); ***F28C 3/06*** (2013.01)

(58) **Field of Classification Search**

CPC B01F 3/04; B01F 3/04468; B01F 3/04466; F28C 3/06; F28F 3/00; F28F 3/005
USPC .... 261/151, 152, 153, 155, 156, 161, 115, 261/117, DIG. 11; 62/304, 305, 310, 314; 165/166, 167, 170
See application file for complete search history.

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(57) **ABSTRACT**

A heat exchange apparatus is provided with an indirect evaporative heat exchange section and a direct evaporative heat exchange section. The indirect evaporative heat exchange section is usually located above the direct evaporative heat exchange section, and an evaporative liquid is passed downwardly onto the indirect heat exchange section. The evaporative liquid that exits the indirect evaporative heat exchange section then passes downwardly across and through the direct heat exchange section. The evaporative liquid is collected in a sump and then pumped upwardly to be distributed again across the indirect heat exchange section. The indirect heat exchange section is comprised of a plate type heat exchanger. An improved heat exchange apparatus is provided with indirect evaporative heat exchange section consisting of a plate type heat exchanger which provides more surface area per volume compared to other designs. The indirect plate style heat exchanger may be combined with one or more direct evaporative heat exchange sections in multiple arrangements.

36 Claims, 9 Drawing Sheets

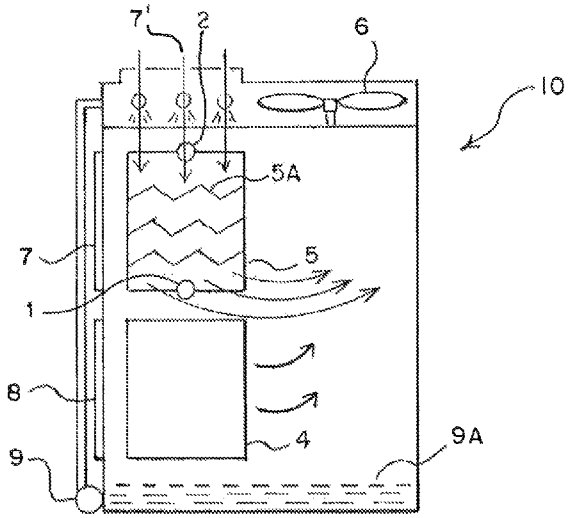


FIG. 1

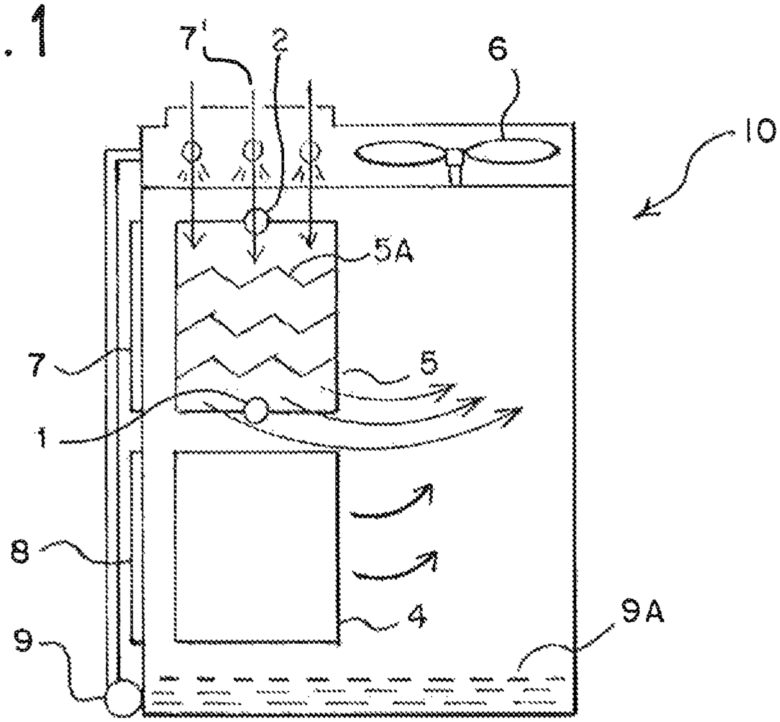


FIG. 2

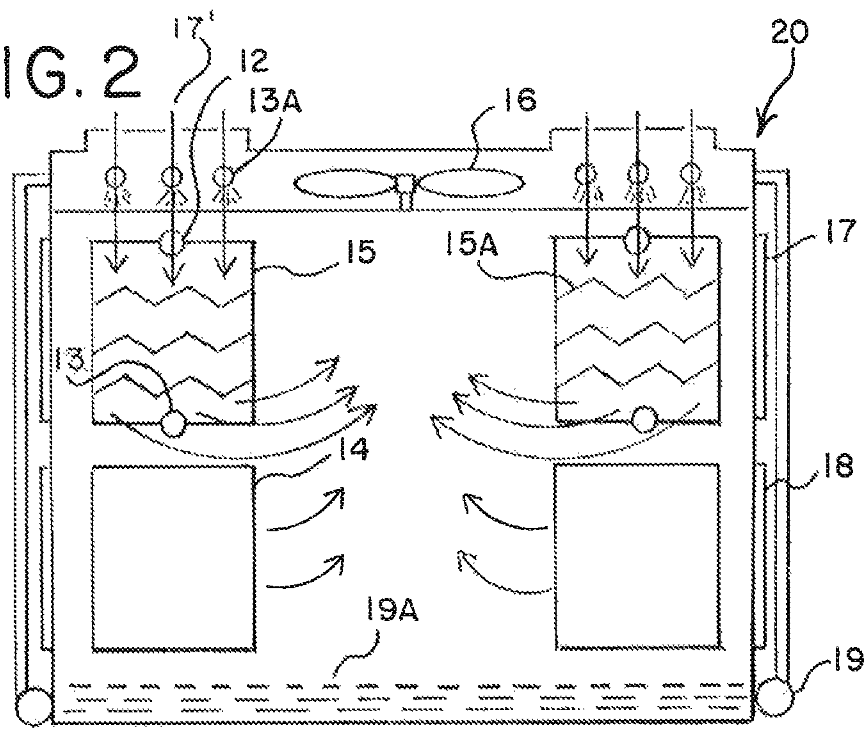
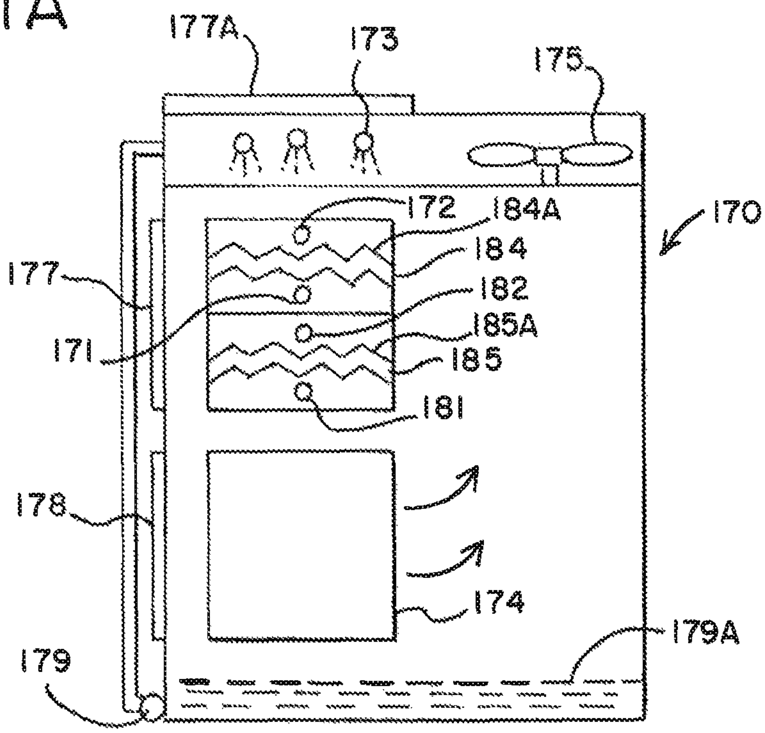


FIG. 1A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184A
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179A
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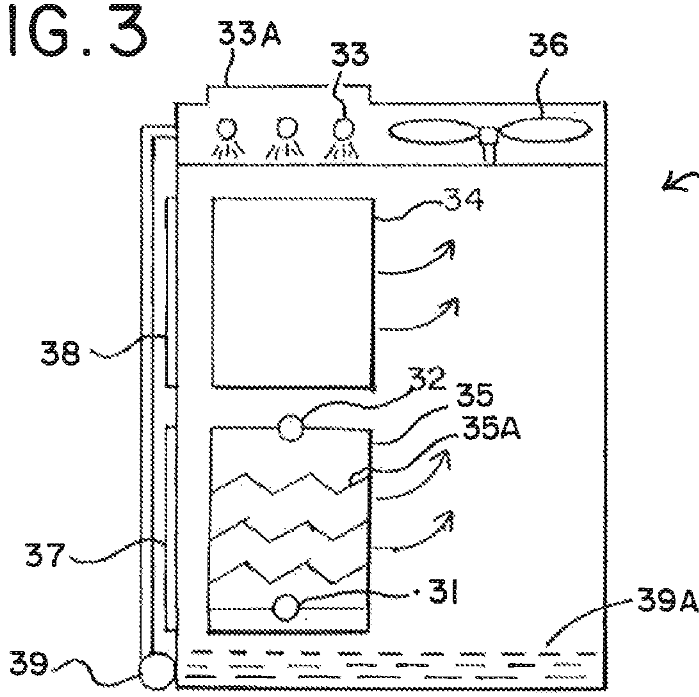
FIG. 3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35A
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39A
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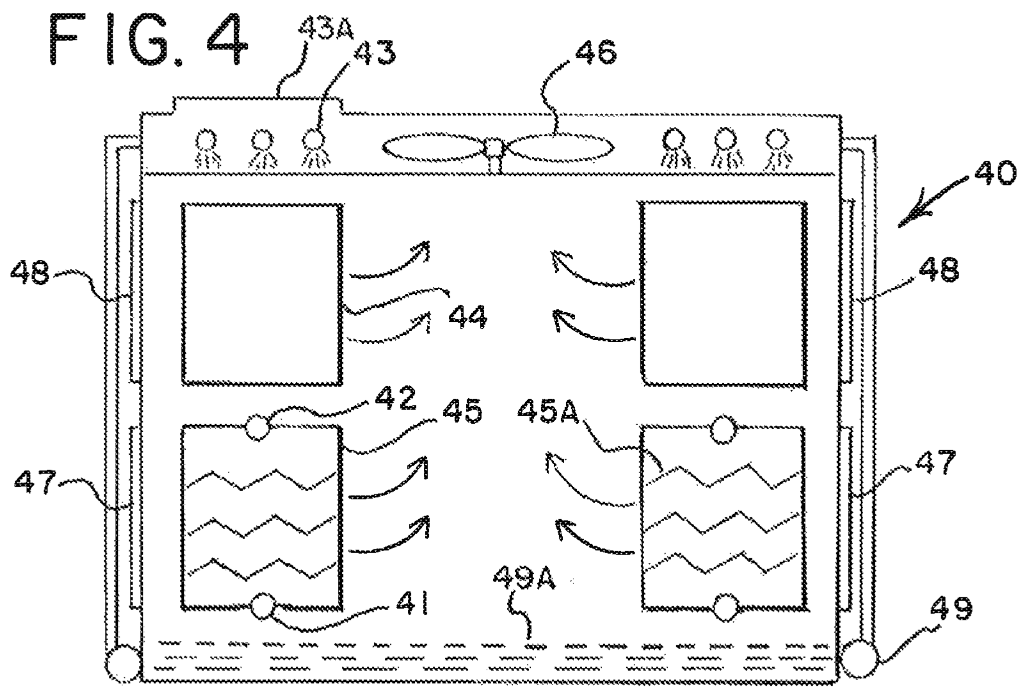
FIG. 4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49A
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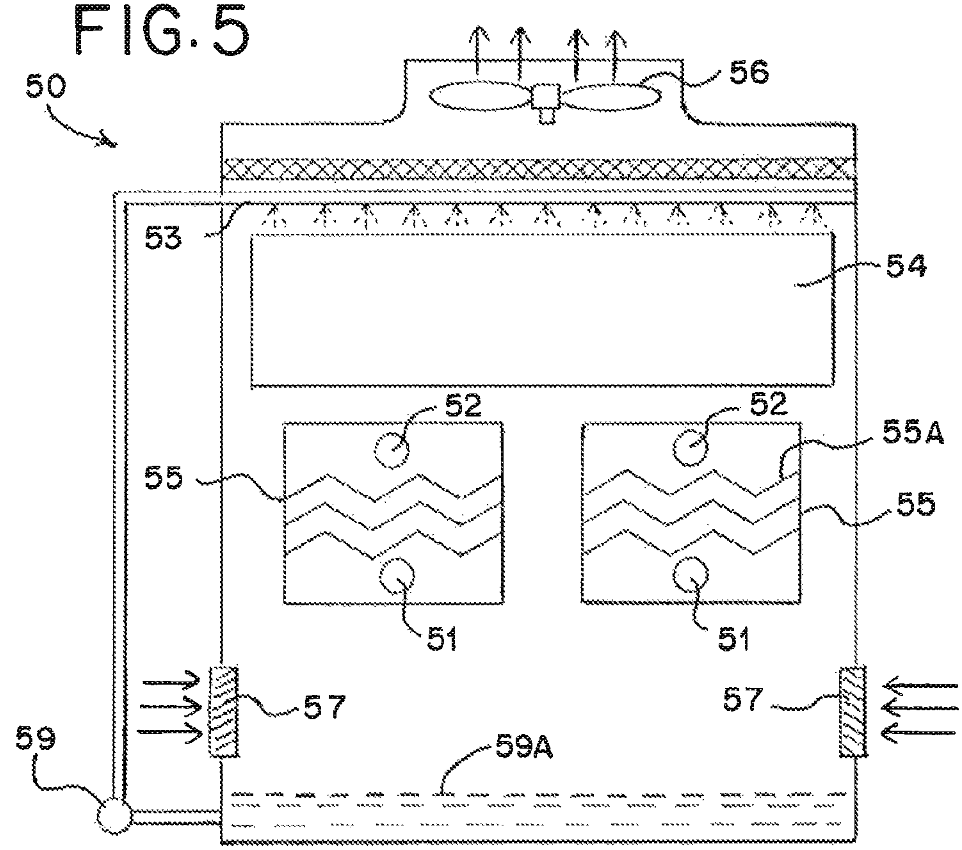
FIG. 5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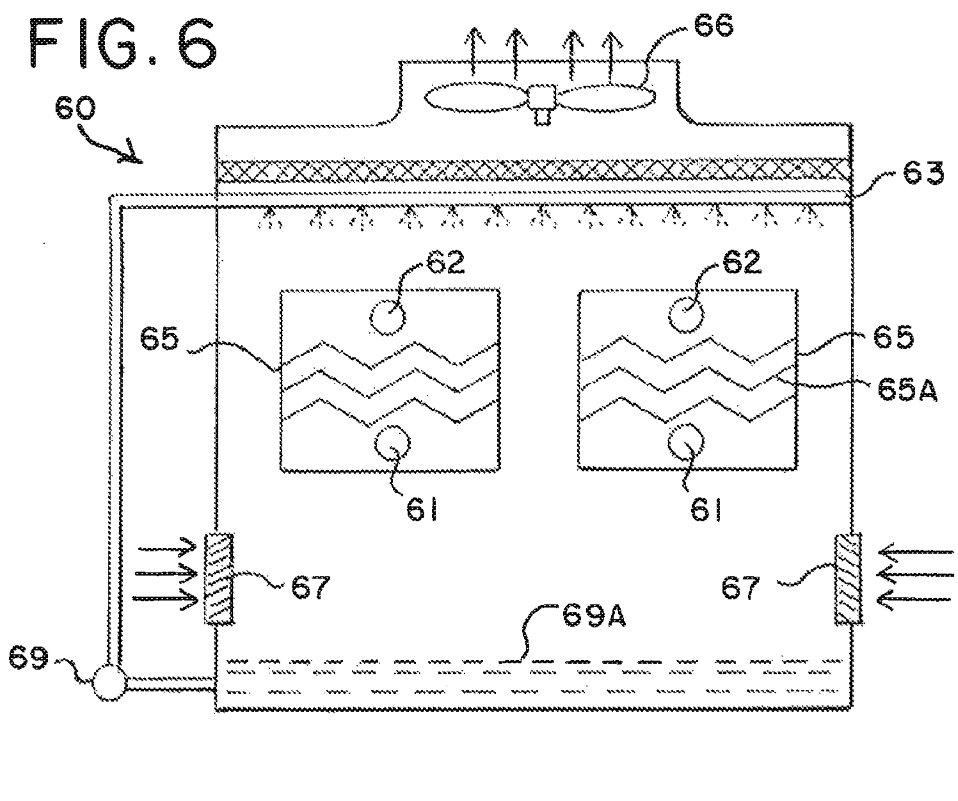
59A

FIG. 6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65A
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69A
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FIG. 7

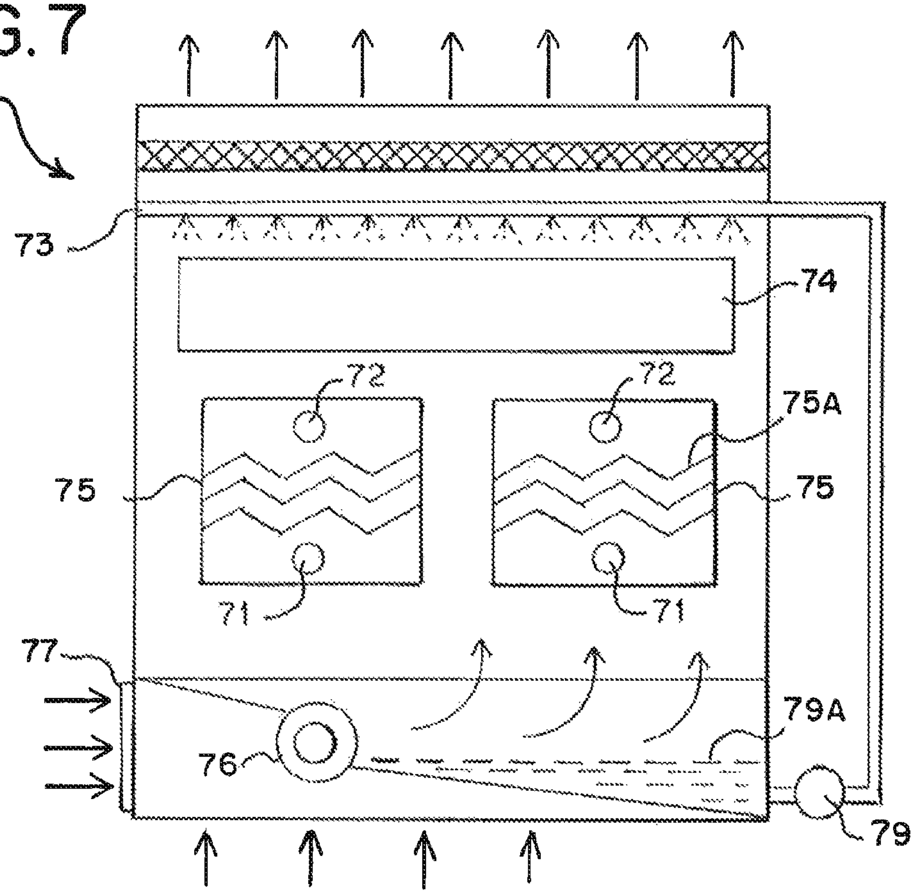

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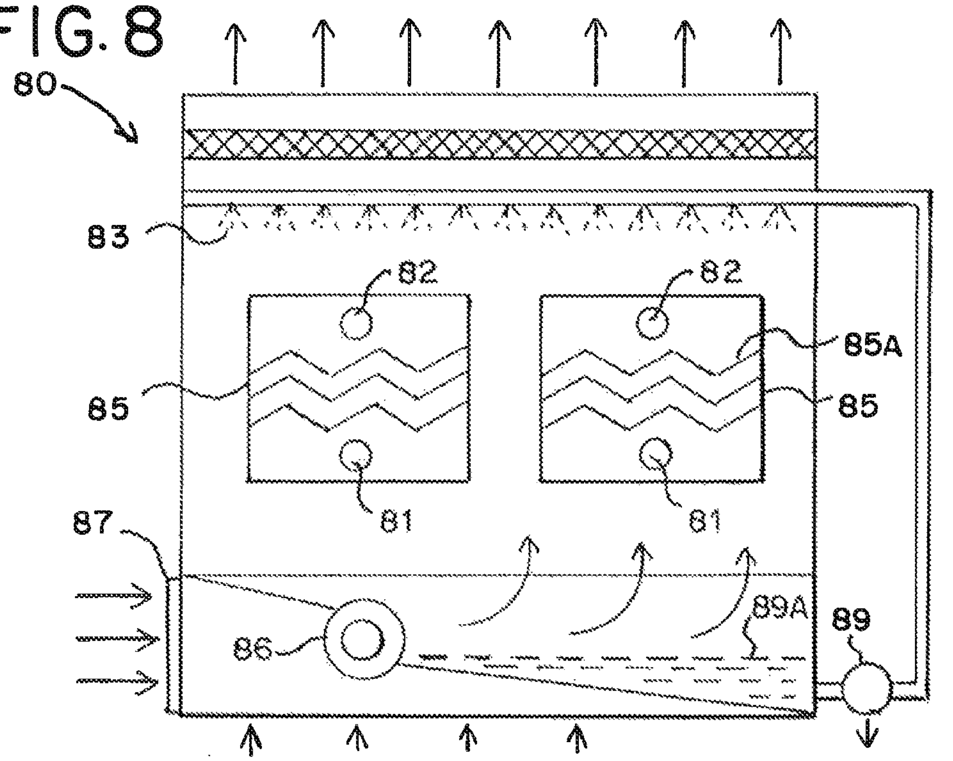
FIG. 8



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85A
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89A
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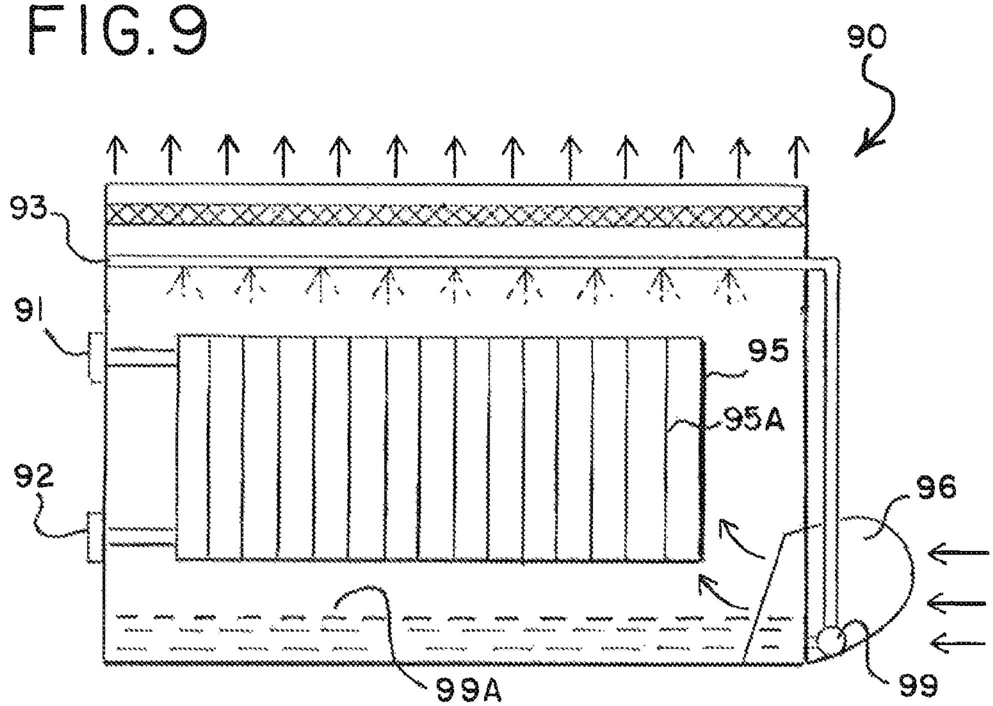
FIG. 9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95A
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99A
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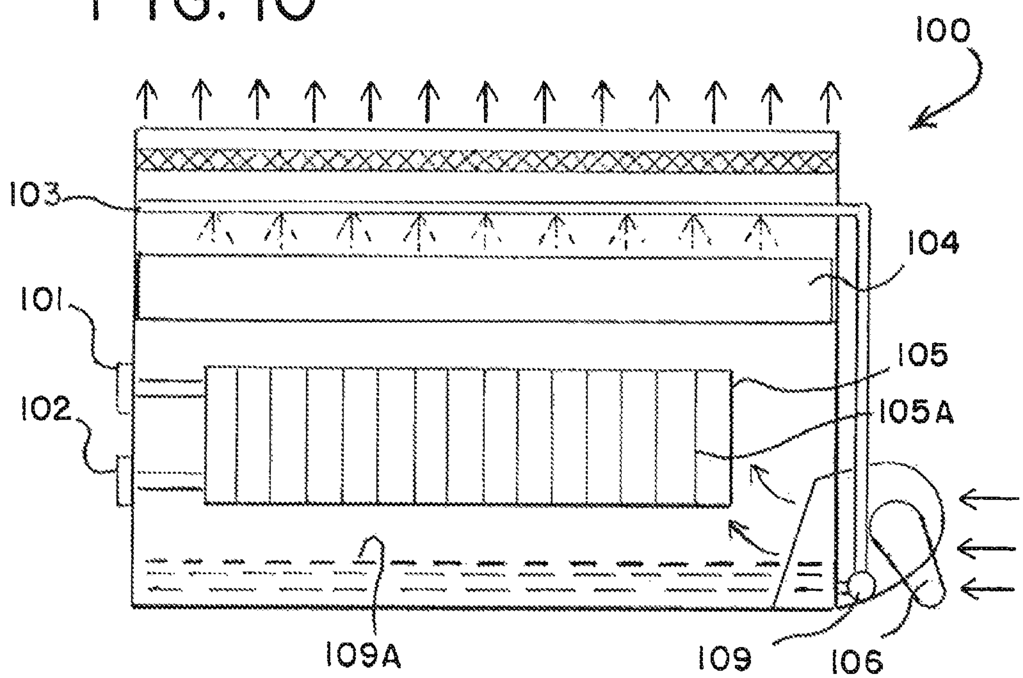
FIG. 10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109A
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106

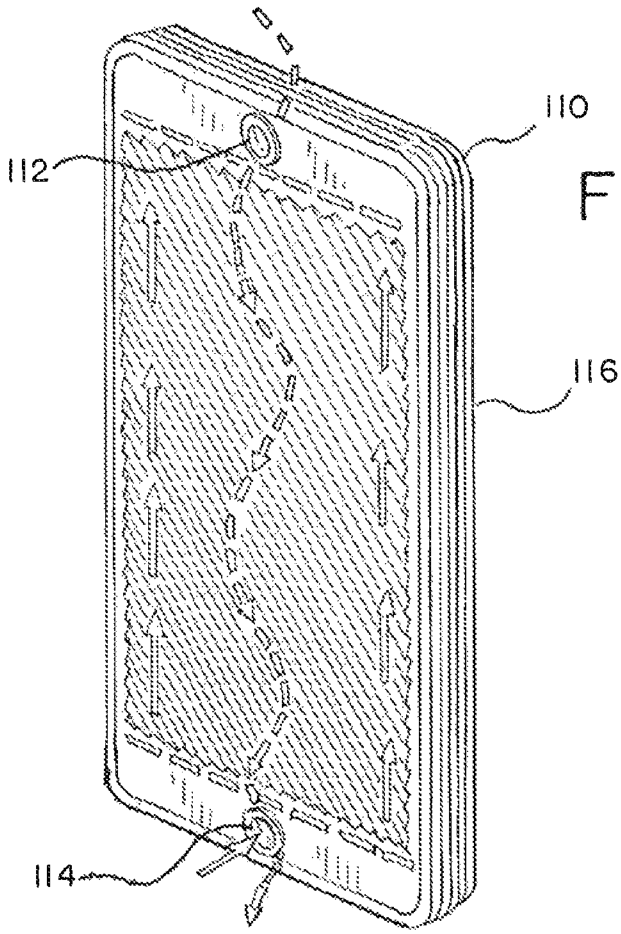


FIG. 11

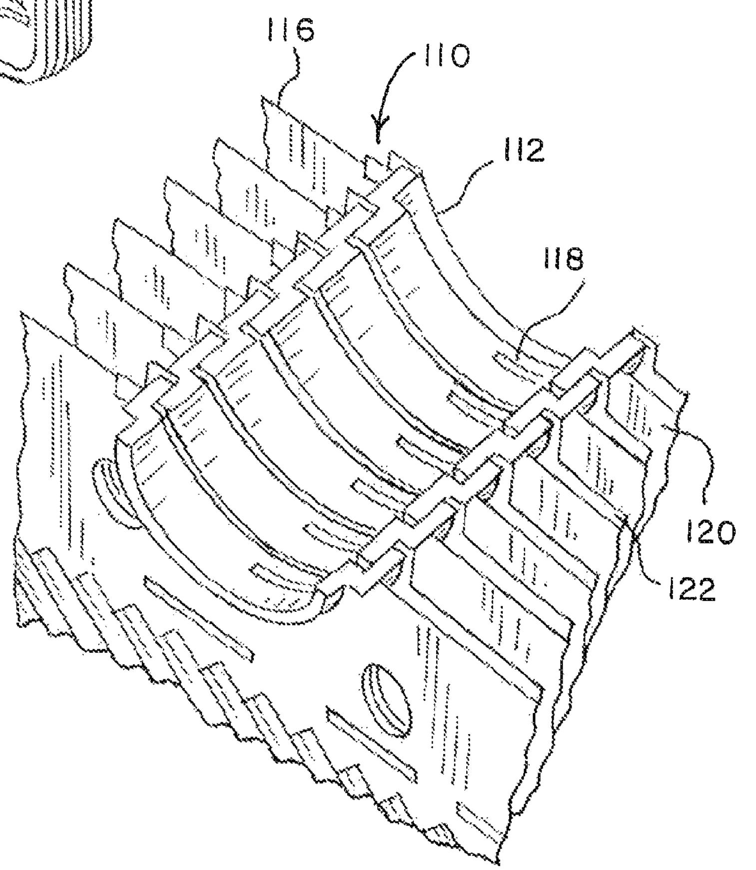
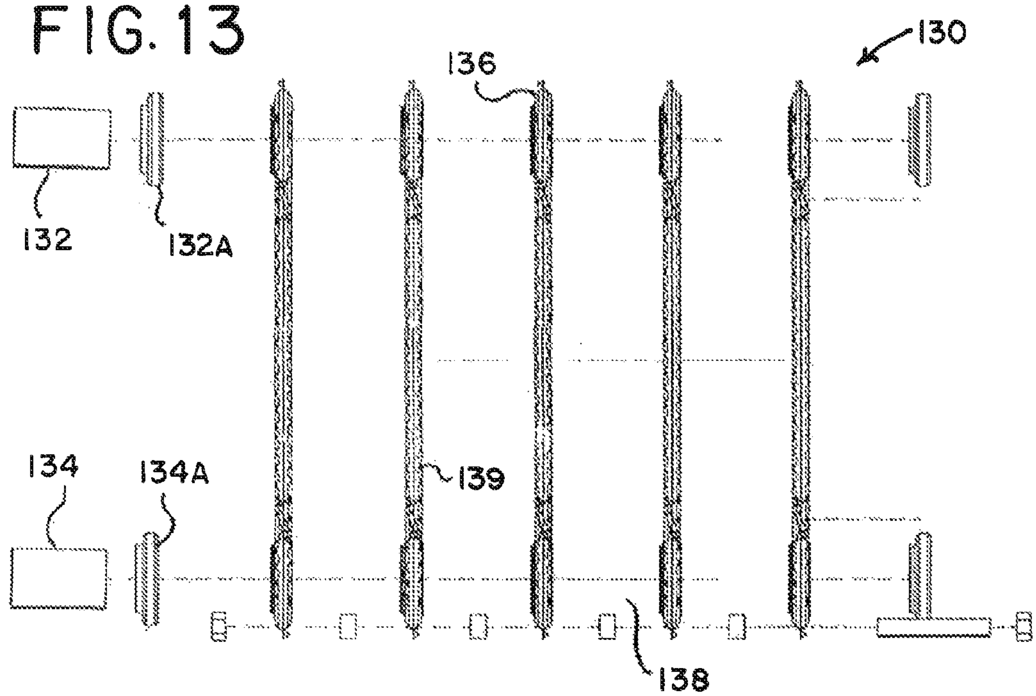


FIG. 12

FIG. 13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134A
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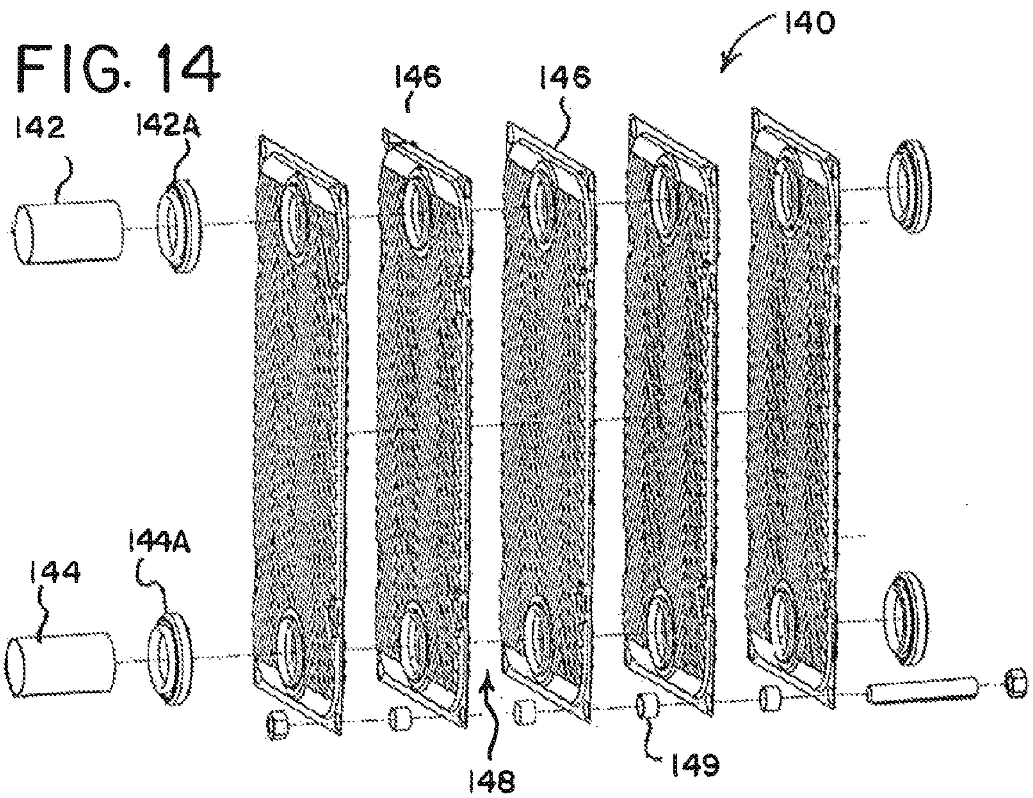
FIG. 14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144A
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FIG. 15

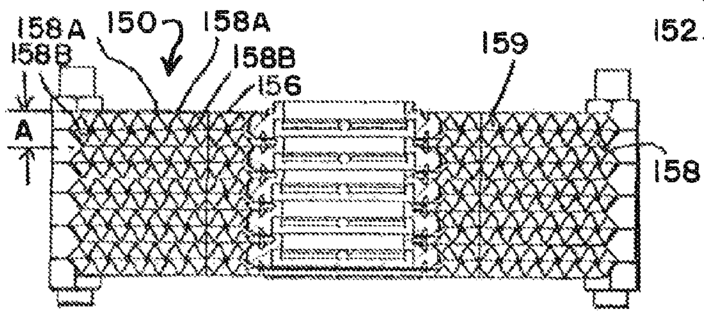


FIG. 16

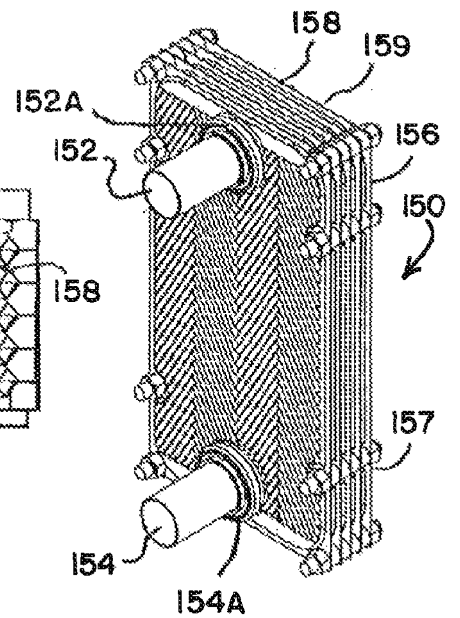


FIG. 17

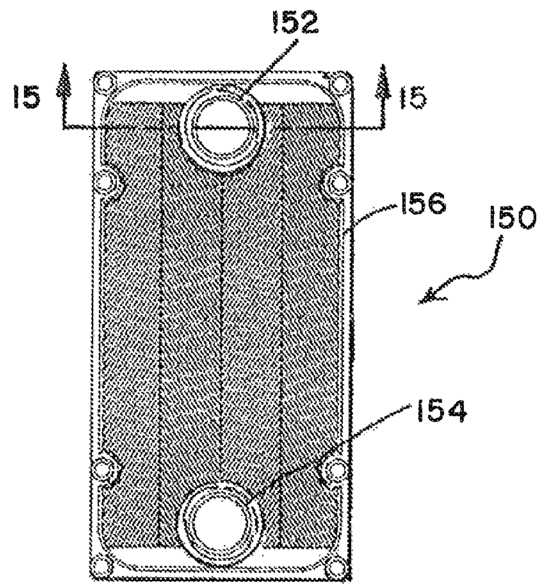
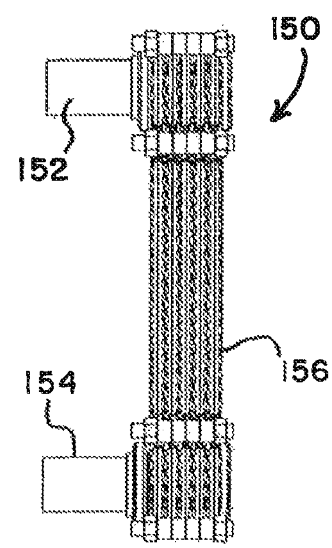


FIG. 18



COOLING TOWER WITH INDIRECT HEAT EXCHANGER

BACKGROUND OF THE INVENTION

The present invention relates generally to an improved heat exchange apparatus such as a closed circuit fluid cooler, fluid heater, condenser, evaporator, thermal storage system, air cooler or air heater. More specifically, the present invention relates to a combination or combinations of separate indirect and direct evaporative heat exchange sections

or components arranged to achieve improved capacity and performance.

The invention includes the use of a plate type heat exchanger as an indirect heat exchange section. When compared with coil circuit indirect heat exchangers which are comprised of individual circuits of tubing, the performance of an indirect heat exchange section comprised of a plate type heat exchanger is improved. Such indirect heat exchange section can be combined with a direct heat exchange section, which usually is comprised of a fill section over which an evaporative liquid such as water is transferred, usually in a downwardly streaming operation. Such combined indirect heat exchange section and direct heat exchange section together provide improved performance as an overall heat exchange apparatus such as a closed circuit fluid cooler, fluid heater, condenser, evaporator, air cooler or air heater.

Part of the improved performance of the indirect heat exchange section comprising a plate heat exchanger is the capability of the indirect heat exchange section as a plate type heat exchanger to provide both sensible and latent heat exchange with the evaporative liquid which is streamed or otherwise transported over and through the indirect heat exchange section. Another important improvement is that plate heat exchangers will have more surface area in the same physical space as other evaporative indirect heat exchangers. Such as indirect heat exchangers comprised, of serpentine coils.

Various combinations of the heat exchange arrangements are possible in accordance with the present invention. Such arrangements could include an arrangement wherein the indirect heat exchange section operates alone, is physically located above the direct heat exchange section or is physically located below the direct heat exchange section. In such an arrangement with indirect section located above the direct section, an evaporative liquid is streamed or otherwise sprayed downwardly onto the indirect heat exchange section with such evaporative liquid, which is usually water, then exiting the indirect section to be transported over the direct heat exchange section which is usually comprised of a fill arrangement. In another arrangement of a combined heat exchange apparatus the indirect heat exchange section is physically located below the direct heat exchange section. In another arrangement of a combined heat exchange apparatus two or more indirect sections are placed in a single closed circuit fluid cooler or heat exchanger each above or below a direct heat exchange section is also part of the present invention. Further, it should be understood that due to varying heat loads and needs of heat exchange, the heat exchanger apparatus or fluid cooler of the present invention could be operated wherein both air and an evaporative liquid such as water are drawn or supplied across both the indirect and direct heat exchange sections. It may be desirable to operate the heat exchanger without a supply of the evaporative liquid, wherein air only would be drawn across the indirect heat exchange section. It is also possible to operate a combined heat exchanger in accordance with the present invention wherein only evaporative liquid would be supplied across or downwardly through the indirect heat exchange section and the direct heat exchange section, and wherein air would not be drawn by typical means such as a fan.

In the operation of an indirect heat exchange section, a fluid stream passing through the internal openings in the plate type heat exchanger is cooled, heated, condensed, or evaporated in either or both a sensible heat exchange operation and a latent heat exchange operation by passing an evaporative liquid such as water together with air in passages between individual plate pairs or cassettes in the indirect heat exchanger. Such combined heat exchange results in a more efficient operation of the indirect heat exchange section. The evaporative liquid, which again is usually water, which passes across or downwardly through the indirect heat exchange section then passes, usually downwardly, across or through the direct heat exchange section which is typically a fill assembly. Heat in the evaporative liquid is passed to air which is drawn generally downwardly, upwardly or across the direct heat exchange section and outwardly from the closed circuit fluid cooler or heat exchanger assembly by an air moving system such as a fan. The evaporative liquid draining from the indirect or direct heat exchange section is typically collected in a sump and then pumped upwardly for redistribution across the indirect or direct evaporative heat exchange section. Of course, as explained above, the indirect and direct heat exchange sections can be reversed wherein, in the reversed situation where a direct heat exchange section would be located above an indirect heat exchange section, the evaporative fluid exiting the indirect section would be collected in a sump and pumped upwardly for distribution across the direct heat exchange section. Alternatively, only the indirect heat exchange section may be present.

Accordingly, it is an object of the present invention to provide an improved heat exchange apparatus, which could be a closed circuit fluid cooler, fluid heater, condenser, evaporator, air cooler or air heater, which includes an indirect heat exchange section and possibly a direct heat exchange section.

It is another object of the present invention to provide an improved heat exchange apparatus such as a closed circuit fluid cooler, fluid heater, condenser, evaporator, air cooler or air heater, including an indirect heat exchange section that comprises a plate type heat exchanger.

It is another object of the invention to provide an improved heat exchange apparatus comprising a plate type heat exchanger with more surface area per volume than other evaporative indirect heat exchangers.

SUMMARY OF THE INVENTION

The present invention provides an improved heat exchange apparatus which typically is comprised of a combination of an indirect heat exchange section and a direct heat exchange section. The indirect heat exchange section provides improved performance by utilizing a plate type heat exchanger as the indirect heat exchange section. The plate type heat exchanger contains more surface area per unit volume that other indirect evaporative heat exchangers. The plate type heat exchanger is comprised of one or more combined plate heat exchange groupings or cassettes each comprised of a pair of plates. Each cassette forms an internal passage between plates. Such plates are designed to allow a fluid stream to be passed there through within the cassette, exposing the fluid stream to a large surface area of one side of each plate in the cassette of the heat exchanger. Outside each plate a space is provided wherein air or an evaporative liquid such as water, or a combination of air and an evaporative liquid, can be passed to provide both sensible and latent heat exchange from the outside surfaces of the plates of the plate heat exchanger. Such utilization of a plate heat exchanger in the closed circuit fluid cooler, fluid heater, condenser, evaporator, air cooler or air heater of the present invention provides improved performance and also allows for combined operation or alternative operation wherein only air or only an evaporative liquid or a combination of the two can be passed through or across the outside of the plates in the plate heat exchanger.

A direct heat exchange section is located generally beneath the indirect heat exchange section whereby the evaporative liquid falling from the indirect heat exchange section is allowed to pass across or through fill and accordingly allow heat to be drawn from such evaporative liquid by a passage of air across or through the direct heat exchange section by air moving apparatus such as a fan. Such evaporative liquid is collected in a sump in the bottom of closed circuit fluid cooler, fluid heater, condenser, evaporator, air cooler or air heater and pumped back for distribution, usually downwardly, across or through the indirect heat exchange section.

It is also part of the present invention to provide an assembly wherein two or more indirect heat exchange sections are located above two or more direct heat exchange sections in a single cooling tower or heat exchanger unit. It is also part of the present invention to reverse the positioning of the indirect and direct heat exchange sections wherein the direct heat exchange section would be located above the indirect section. Accordingly an evaporative liquid would be passed initially downwardly through the direct heat exchange fill section, with the evaporative liquid falling from the direct heat exchange section to the indirect heat exchange section.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings,

FIG. **1** is a side view of a first embodiment of a heat exchanger in accordance with the present invention;

FIG. **1**A is a side view of another embodiment of a heat exchanger in accordance with the present invention;

FIG. **2** is a side view of a second embodiment of a heat exchanger in accordance with the present invention;

FIG. **3** is a side view of a third embodiment of a heat exchanger in accordance with the present invention;

FIG. **4** is side view of a fourth embodiment of a heat exchanger in accordance with the present invention;

FIG. **5** is a side view of a fifth embodiment of a heat exchanger in accordance with the present invention;

FIG. **6** is a side view of a sixth embodiment of a heat exchanger in accordance with the present invention;

FIG. **7** is a side view of a seventh embodiment of a heat exchanger in accordance with the present invention;

FIG. **8** is a side view of an eighth embodiment of a heat exchanger in accordance with the present invention;

FIG. **9** is a side view of a ninth embodiment of a heat exchanger in accordance with the present invention;

FIG. **10** is a side view of a tenth embodiment of a heat exchanger in accordance with the present invention;

FIG. **11** is a perspective view of a plate heat exchanger in accordance with an embodiment of the present invention;

FIG. **12** is a partial view of a plate heat exchanger in accordance with an embodiment of the present invention;

FIG. **13** is a side view of a plate heat exchanger with plates separated in accordance with the present invention;

FIG. **14** is a side view of a plate heat exchanger showing places separated in accordance with the present invention;

FIG. **15** is a top view of a plate heat exchanger in accordance with the present invention;

FIG. **16** is a perspective view of an assembled plate heat exchanger in accordance with the present invention;

FIG. **17** is an end view of a plate heat exchanger in accordance with the present invention, and

FIG. **18** is a side view of a plate heat exchanger in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1** of the drawings, a heat exchanger in accordance with a first embodiment of the present invention is shown generally at **10**. Such heat exchangers generally are present in a closed circuit cooling tower with a direct heat exchange section **4** and an indirect heat exchange section **5** located above direct heat exchange section **4**. Direct heat exchange section **4** is typically comprised of fill usually comprised of sheets of polyvinyl chloride. Direct heat exchange section **4** receives air through air inlet **8** on the outside of heat exchanger **10**, with air being drawn generally across and somewhat upwardly through direct heat exchange section **4** by fan **6**. Indirect heat exchange section **5** is usually comprised of plate type heat exchanger **5**A having a fluid outlet **2** and a fluid inlet **1**. It should be understood that the operation of fluid outlet **2** and fluid inlet **1** can be reversed if it is desired. The preferred air direction through the indirect heat exchange section **5** is to enter from the top of the water distribution assembly **3**. Air is then drawn generally downwardly from the top through the indirect heat exchanger section **5** and exits from the bottom of section **5** by fan **6**. In addition, air can also be optionally drawn through air inlet **7** and generally downwardly across and upwardly through indirect heat exchange section **5** by fan **6** with the top of the water distribution assembly **7**' open or closed. An evaporative liquid, usually water, flows downwardly from water distribution assembly **3** such that the evaporative liquid falls downwardly and through indirect heat exchange section **5**. The evaporative liquid that passes through indirect heat exchange section **5** passes downwardly and through direct heat exchange section **4**. The evaporative liquid that passes downwardly and out from direct heat exchange section **4** is collected in sump **9**A and is pumped upwardly by pump **9** for redistribution through water distribution assembly **3**. Water distribution assembly **3** can be comprised of a variety of pipes with openings, or any other water distribution arrangement such as using spray nozzles, troughs, or other water distribution assemblies. Indirect heat exchange section **5** is usually comprised of a plate type heat exchanger **5**A. A fluid to be cooled, condensed, heated, or evaporated, passes within the joined plates or cassettes of plate heat exchanger **5**A.

Referring now to FIG. **1**A of the drawings, a heat exchanger in accordance with another embodiment of the present invention is shown generally at **170**. Such heat exchangers generally are present in a closed circuit cooling tower with a direct heat exchange section **174** and two indirect heat exchange sections **184** and **185** located above direct heat exchange section **174**. Direct heat exchange section **174** is typically comprised of fill usually comprised of sheets of polyvinyl chloride. Direct heat exchange section **174** receives air through air inlet **178** on the outside of heat exchanger **170**, with air being drawn generally across and somewhat upwardly through direct heat exchange section **174** by fan **175**. The first indirect heat exchange section **184** is usually comprised of plate type heat exchanger **184A** having a fluid outlet **172** and a fluid inlet **171**. The second indirect heat exchange section **185** is usually comprised of plate type heat exchanger **185**A having a fluid outlet **182** and a fluid inlet **181**. It should be understood that the operation of fluid outlets **172** and **182** and fluid inlets **171** and **181** can be reversed if it is desired. The preferred air direction through the indirect heat exchange sections **184** and **185** is to enter from the top of the water distribution assembly **173**. Air is then drawn generally downwardly from the top through the indirect heat exchanger sections **184** and **185** and exits from the bottom of section **184** and **185** by fan **175**. In addition, air can also be optionally drawn through air inlet **177** and generally downwardly across and upwardly through indirect heat exchange section **184** and **185** by fan **175** with the top of the water distribution assembly **177**A open or closed. An evaporative liquid, usually water, flows downwardly from water distribution assembly **173** such that the evaporative liquid falls downwardly and through indirect heat exchange sections **184** and **185**. The evaporative liquid that passes through indirect heat exchange sections **184** and **185** passes downwardly and through direct heat exchange section **174**. The evaporative liquid that passes downwardly and out from direct heat exchange section **174** is collected in sump **179**A and is pumped upwardly by pump **179** for redistribution through water distribution assembly **173**. Water distribution assembly **173** can be comprised of a variety of pipes with openings, or any other water distribution arrangement such as using spray nozzles, troughs, or other water distribution assemblies. Indirect heat exchange sections **184** and **185** are usually comprised of a plate type heat exchanger **184** and **185**A, respectively. Two fluids to be cooled, condensed, heated, or evaporated, pass independently within the joined plates or cassettes of plate heat exchanger **184** and **185**A as separate fluid streams.

FIG. **2** is a side view of the second embodiment of heat exchanger **20** in accordance with a second embodiment of the present invention. Heat exchanger **20** is usually a closed circuit cooling tower including an indirect heat exchange section **15** located above a direct heat exchange section **14**, with the understanding that two such indirect and direct sections are provided as part of heat exchanger **20**. Direct heat exchange section **14** is again comprised of fill sheets of a suitable material such as polyvinyl chloride. Air to be passed across and generally crossways through direct heat exchange section **14** enters through air inlet **18** and is drawn by fan **16**. Indirect heat exchange section **15** is usually comprised of a plate heat exchanger **15**A. The preferred air direction through the indirect heat exchange section **15** is to enter from the top of the evaporative liquid distribution arrangement **13**A. Air is then drawn generally downwardly from the top through the indirect heat exchanger section **15** and exits from the bottom of section **15** by fan **16**. In addition, air can also be optionally drawn downwardly, across and generally upwardly through indirect heat exchange section **15** entering through air inlet **17** by fan **16** with the top of the liquid distribution arrangement ent **17**' open or closed. Evaporative liquid is provided to flow downwardly from an evaporative liquid distribution arrangement **13**A. Such evaporative liquid passes generally downwardly across indirect heat exchange section **15**. The evaporative liquid that exits indirect heat exchange section **15** passes downwardly through direct heat exchange section **14** and is collected in sump **19**A. Such collected evaporative liquid is pumped by pump **19** upwardly for distribution to water evaporative liquid distribution assembly **13**A. Plate heat exchanger **15**A includes fluid outlet **12** and fluid inlet **13**, which can be reversed if it is desired. A fluid to be cooled, condensed, heated or evaporated passes within the joined plates or cassettes of plate heat exchanger **15**A.

It should be understood in the operation of heat exchanger **10** and heat exchanger **20** described above, that depending on the performance required, both such heat exchangers may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan drawing air across and through the direct and indirect heat exchange sections. If a lesser degree of heat exchange is required, it is possible to operate without the fan drawing air across the indirect and direct sections, such that only the evaporative liquid would exit and pass downwardly and through the indirect and direct heat exchange sections. Finally, the unit may be operated such that the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing within the indirect heat exchange section joined plate pairs being cooled by air passing downwardly or across and upwardly drawn by the fan in the heat exchanger or cooling tower.

Referring now to FIG. **3** of the drawings, the third embodiment of a heat exchanger is shown generally at **30**, in the form of a closed circuit cooling tower. Heat exchanger **30** is comprised of a direct heat exchange section **34** which is located generally above an indirect heat exchange section **35**. Direct heat exchange section **34** is usually comprised of a fill sheet assembly wherein the fill sheets are typically comprised of polyvinyl chloride. Air enters through air inlet **38** and is drawn by fan **36** across and upwardly through direct heat exchange section **34**. An evaporative liquid usually water is distributed downwardly from evaporative liquid distribution assembly **33**; such evaporative liquid passes downwardly and through direct heat exchange section **34**. The top **33**A of the evaporative liquid distribution assembly **33**, is usually closed. Indirect heat exchange section **35** is usually comprised of a plate heat exchanger **35**A which is comprised of a series of joined plate cassettes with separated spaces between each cassette. Fluid to be cooled, heated, condensed or evaporated enters through fluid inlet **31** and exits through fluid outlet **32**, although such can be reversed if it is desired. Air passes through the indirect heat exchange section **35** and between plate pairs or cassettes of the plate heat exchanger entering through air inlet **37** and drawn by fan **36**. Note that air inlet **38** can be partially open to change the air flow ratio between the indirect and the direct heat exchange sections or can be fully closed which allows the full amount of air entering the direct heat exchange section. Evaporative liquid falling from direct heat exchange section **34** passes between the plate pairs or cassettes of plate heat exchanger **35** and provides both sensible and latent heat transfer of the fluid passing within the joined plates in plate heat exchanger **35**A. Such evaporative liquid is collected in sump **39**A and is pumped upwardly through using pump **39** for redistribution through evaporative distribution assembly **33**.

Referring now to FIG. **4**, a fourth embodiment of a heat exchanger assembly is shown generally at **40** in accordance with the present invention. In this embodiment two direct heat exchanger sections **44** are located above two indirect heat exchanger sections **45**. Evaporative liquid exits evaporative liquid distribution assembly **43** and is distributed downwardly through direct heat exchange section **44** which is usually comprised of a series of fill sheets made of polyvinyl chloride. The top **43**A of the evaporative liquid distribution assembly **43**, is usually closed. Air passed across and generally upwardly through direct heat exchange section **44** entering through air inlet **48** and with air drawn by fan **46**. Note that air inlet **48** can be partially open to change the air flow ratio between the indirect and the direct heat exchange sections or can be fully closed which allows the full amount of air entering the direct heat exchange section. Indirect heat exchange section **45** is usually comprised of a series of plate heat exchangers **45**A. Such plate heat exchangers allow a fluid to be passed through the joined plates or cassettes thereby exposing such fluid to a large surface area of the plates themselves. Such plates are usually arranged such that a space between each joined plate pair or cassette is provided for the evaporative liquid to be passed there through, currently with air, to allow both sensible and latent heat transfer of the evaporative liquid passing between the plates. Further air enters and passes across and upwardly through the plate heat exchanger **45**. Air is drawn through air inlet **47** and outwardly by fan **46**. Evaporative liquid passing downwardly through indirect heat exchange section **45** is collected in sump **49**A and is pumped upwardly by pump **49** to be distributed again through evaporative liquid distribution assembly **43**.

It should be understood in the operation of heat exchanger **30** and heat exchanger **40** described above, that depending on the performance required, both such heat exchangers may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan drawing air across and through the direct and heat exchange sections. It is possible to operate without the fan drawing air across the indirect and direct sections, such that only the evaporative liquid would exit and pass downwardly and through the indirect and direct heat exchange sections. Finally, it is possible that the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing through the indirect heat exchange section joined plate pairs or cassettes being cooled, heated, condensed, or evaporated by air passing across and upwardly there through drawn by the fan in the heat exchanger or cooling tower.

Referring now to FIG. **5**, a fifth embodiment of the present invention is shown as a heat exchanger in a closed circuit cooling tower assembly **50**. Such heat exchanger is shown to be comprised of a direct heat exchange section **54** located generally above two indirect heat exchange sections **55**. Direct heat exchange section **54** is usually comprised of a series of fill sheets with each fill sheet being comprised of polyvinyl chloride. Each indirect heat exchange section is comprised of a plate heat exchanger arrangement having a fluid outlet **52** and a fluid inlet **51**, which can be reversed if it is desired. Air is drawn inwardly through air inlets **57** by fan **56**. Evaporative liquid passes from evaporative distribution assembly **53** downwardly and through direct heat exchange section **54**. Evaporative liquid passing through direct heat exchange section **54** passes downwardly through both indirect heat exchange sections **55**. Evaporative liquid passing from indirect heat exchange sections **55** is collected in sump **59**A, and is pumped upwardly by pump **59** for distribution through evaporative liquid distribution assembly **53**. Indirect heat exchange section **55** is comprised of a collection of joined plate pairs or cassettes **55**A. Each plate pair is separated such that evaporative liquid passing downwardly through indirect heat exchange section **55** can draw heat from the fluid within plate pairs **55**A sensibly by contact with the outside of the plates. All of the heat is eventually released to the air from the evaporative fluid in both latent and sensible fashions in the evaporative passage.

It should be understood in the operation of heat exchanger **50** described above, that depending on the performance required, such heat exchanger may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan drawing air across and through the direct and indirect heat exchange sections. It is possible to operate without the fan drawing air across the indirect and direct sections, such that only the evaporative liquid would exit and pass downwardly and through the indirect and direct heat exchange sections. Finally, it is possible again that the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing through the indirect heat exchange section plates being cooled, heated, condensed, or evaporated by air passing across and upwardly there through drawn by the fan in the heat exchanger or cooling tower.

Referring now to FIG. **6**, a sixth embodiment of the present invention is shown generally as heat exchanger **60**, which is usually a closed circuit cooling tower. Heat exchanger or cooling tower **60** is seen to be comprised of indirect heat exchange sections **65**. Each indirect heat exchange section **65** is seen to be usually comprised of plate heat exchangers **65**A, which are present as assemblies. Indirect heat exchange section **65** has a fluid outlet **61** and a fluid inlet **62**, which can be reversed if it is desired. An evaporative liquid, usually water, is discharged from evaporative liquid distribution assembly **63** generally downwardly such that evaporative liquid passes downwardly and through indirect heat exchange section **65**. Air is seen to be drawn inwardly through air inlets **67** generally upwardly through indirect heat exchange section **65** by fan **66**. Further, evaporative liquid that passes through indirect heat exchange section **65** is collected in sump **69**A and is pumped upwardly by pump **69** for redistribution through evaporative liquid distribution assembly **63**. Evaporative liquid **63** that passes through plate heat exchanger **65** absorbs heat by contacting the large plate surface of plate heat exchanger **65**A to absorb heat from the fluid within plate pairs **65**A in a sensible fashion. All of the heat is eventually released to the air from the evaporative fluid in both latent and sensible fashions in the evaporative passage.

It should be understood in the operation of heat exchanger **60** described above, that depending on the performance required, such heat exchanger may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan drawing air up and through the indirect heat exchange sections. If a lesser degree of heat exchange is required, it is possible to operate without the fan drawing air up and through the indirect section, such that only the evaporative liquid would exit and pass downwardly and through the indirect section. Further, if the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing through the indirect heat exchange section plates being cooled, heated, condensed, or evaporated by air passing up and upwardly there through drawn by the fan in the heat exchanger or cooling tower. Further, the heat exchanger may be operated with the fan drawing air up and through one of the two indirect sections, with or without the evaporative liquid being supplied.

Referring now to FIG. **7**, a seventh embodiment of the present invention is shown generally as heat exchanger **70**, which is generally in the form of a closed circuit cooling tower. Heat exchanger **70** is seen to be comprised of a direct heat exchange section **74** for above two indirect heat exchange sections **75**. Direct heat exchange section **74** is usually comprised of a series of fill sheets each comprised of polyvinyl chloride. Each indirect heat exchange section **75** is seen to be comprised of a series of joined plates or cassettes **75**A with fluid outlet **72** and fluid inlet **71**. These fluid inlet and outlet can be reversed if it is desired. Evaporative liquid is discharged from evaporative distribution assembly **73** downwardly onto and through direct heat exchange section **74**. Evaporative liquid that passes through direct heat exchange section **74** passes downwardly and through indirect heat exchange sections **75**. Evaporative liquid that passes through and out of indirect heat exchange sections **75** is collected in sump **79**A and pumped upwardly by pump **79** for distribution through evaporative liquid distribution assembly **73**. Air enters heat exchanger **70** through air inlet **77** and is drawn inwardly by centrifugal fan **76** and pushed upwardly, or in a counter flow direction, with respect to the evaporative liquid, through indirect heat exchange section **75** and direct heat exchange section **74**. Evaporative liquid that passes through indirect heat exchange section **75** passes between the joined plates or cassettes of plate heat exchangers **75**A thereby providing cooling, heating, evaporating, or condensing to the fluid passing through the joined plate pairs of plate heat exchangers **75**A. Further, the evaporative liquid passes downwardly through indirect heat exchange section **75** passes between the joined plates of plate heat exchanger **75**A along with air to thereby allow both sensible and latent heat exchanges of the fluid passing through the joined plate pairs of heat exchanger **75**A.

It should be understood in the operation of heat exchanger **70** described above, that such heat exchanger may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan drawing air up and through the direct and indirect heat exchange sections. It is possible to operate without the fan drawing air up and through the indirect and direct sections, such that only the evaporative liquid would exit and pass downwardly and through the indirect and direct heat exchange sections. Finally, it is possible again that the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing through the indirect heat exchange section plates being cooled, heated, condensed, or evaporated by air passing upwardly there through drawn by the fan in the heat exchanger or cooling tower.

Referring now to FIG. **8**, an eighth embodiment of the heat exchanger in accordance with the present invention is shown generally at **80** which is shown in the form of heat exchanger or closed circuit cooling tower. Heat exchanger **80** is seen to be comprised of a pair of indirect heat exchange sections **85**. Each indirect heat exchange section **85** is comprised of a series of joined plates or cassettes **85**A. Indirect heat exchange section **85** also includes a fluid outlet **81** and a fluid inlet **82**, which can be reversed as it is desired. Evaporative liquid is provided by evaporative liquid distribution assembly **83** to pass downwardly and through each indirect heat exchange section **85**. Such evaporative liquid that passes through indirect heat exchange sections **85** is collected in sump **89**A and is pumped upwardly by pump **89** back to evaporative liquid distribution assembly **83**. Air that is drawn in air inlet **87** by centrifugal fan **86** passes generally upwardly or in a counter flow direction through indirect heat exchange sections **85**. Evaporative liquid that passes through heat exchange section **85** passes between the joined plate pairs or cassettes of plate heat exchanger **85**A such that the fluid passing through the joined plates of exchanger **85**A is cooled, heated, condensed, or evaporated both sensibly and in a latent manner by such evaporative liquid passing downwardly over the outer surface area of the joined plates of plate heat exchanger **85**A along with air.

It should be understood in the operation of heat exchanger **80** described above, that such heat exchanger may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan drawing air up and through the indirect heat exchange section. It is possible to operate without the fan pushing air up and through the indirect section, such that only the evaporative liquid would exit and pass downwardly and through the indirect heat exchange section. Finally, it is possible again that the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing through the indirect heat exchange section plates being cooled, heated, condensed, or evaporated by air passing upwardly there through pushed by the fan in the heat exchanger or closed circuit cooling tower.

Referring now to FIG. **9**, a ninth embodiment of the present invention is shown generally at **90** as a heat exchanger or a closed circuit cooling tower. Heat exchanger **90** is seen to be comprised of an indirect sections **95**. Indirect heat exchange section **95** is seen to be comprised of a series of joined plates or cassettes **95**A with fluid outlet **92** and fluid inlet **91**. It should be understood that fluid outlet and fluid inlet **92** and **91** can be reversed if it is desired. As the embodiment shown in FIG. **9** of heat exchanger **90** is generally of a low profile arrangement, centrifugal fan **96** is seen to be located outside the structure of heat exchanger **90** to thereby draw air inwardly through the fan structure to be passed generally upwardly through and across indirect heat exchange section **95**. Evaporative liquid is distributed downwardly from evaporative liquid distribution assembly **93** to pass downwardly through indirect heat exchange section **95**. Such evaporative liquid that passes out from indirect heat exchange assembly **95** is collected in sump **99**A and is pumped upwardly by pump **99** for redistribution through evaporative liquid distribution assembly **93**. Evaporative liquid that passes through heat exchange section **95** passes between the joined plate pairs or cassettes of plate heat exchanger **95**A such that the fluid passing through inside of the joined plates of exchanger **95**A is cooled, heated, condensed, or evaporated both sensibly and in a latent manner by such evaporative liquid passing downwardly over the outer surface area of the joined plates of plate heat exchanger **95**A along with air.

It should be understood in the operation of heat exchanger **90** described above, that such heat exchanger may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan pushing air up and through the indirect heat exchange section. It is possible to operate without the fan pushing air up and through the indirect section, such that only the evaporative liquid would exit and pass downwardly and through the indirect heat exchange section. Finally, it is possible again that the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing through the indirect heat exchange section plates being cooled, heated, condensed, or evaporated by air passing upwardly there through pushed by the fan in the heat exchanger or cooling tower.

Referring now to FIG. **10**, a tenth embodiment of the present invention is shown generally as a heat exchanger **100** or in the form of a closed circuit cooling tower. Heat exchanger **100** is seen to be comprised of an indirect heat exchange section **105** located generally below a direct heat exchange section **104**. Direct heat exchange section **104** is usually comprised of a series of fill sheets each comprised of a polyvinyl chloride. Indirect heat exchange section **105** is usually comprised of a series of plate heat exchanger pairs or cassettes **105**A, having a fluid outlet **101** and a fluid inlet **102**. If it desired, such fluid inlet and outlet can be reversed. Air is seen to be drawn inwardly by fan **106** which is located outside the physical structure or attached to the outside of the physical structure of heat exchanger **100**. This is usually centrifugal fan **106** which brings air inwardly near the side or bottom of heat exchanger **100** and near one end thereof such air is forced upwardly through and across indirect heat exchange section **105** and generally upwardly in a counter-flow direction, with respect to the evaporative liquid, through direct heat exchange section **104**. Evaporative liquid is distributed downwardly from evaporative liquid distribution assembly **103**. Such evaporative liquid passes downwardly through direct heat exchange section **104**. The evaporative liquid that exits direct heat exchange section **104** passes downwardly through indirect heat exchange section **105** and is collected in a sump **109**A. Such collected evaporative liquid is pumped from sump **109**A by pump **109** back to water distribution assembly **103**. Plate heat exchanger pairs or cassettes **105**A are typically spaced from each other such that the fluid passing inside the plates of plate heat exchanger **105** is cooled, heated, condensed, and evaporated both sensibly and in a latent manner by the evaporative liquid passing on the outside of the plate pairs of plate heat exchanger **105** and also by the air being drawn by a counter-current manner across and generally upwardly through indirect heat exchange section **105**.

It should be understood in the operation of heat exchanger **100** described above, that such heat exchanger may be operated with both evaporative liquid exiting the evaporative liquid distribution system and the fan forcing air up and through the direct and indirect heat exchange sections. It is possible to operate without the fan forcing air up and through the indirect and direct sections, such that only the evaporative liquid would exit and pass downwardly and through the indirect and direct heat exchange sections. Finally, it is possible again that the evaporative liquid would not be supplied through the evaporative liquid distribution assembly, and the heat exchanger would operate only with the fluid passing through the indirect heat exchange section plates being cooled, heated, condensed, or evaporated by air passing across and upwardly there through forced by the fan in the heat exchanger or cooling tower.

Referring now to FIGS. **11** and **12**, a view of a plate heat exchanger in accordance with the present invention is shown generally at **110**. Each plate heat exchanger is shown to be comprised of a series of joined pairs or cassettes of plates **116** spaced from each other. A fluid outlet header is shown at **112** and a fluid inlet header is shown at **114**. As shown in FIG. **12**, in a detailed breakaway view, fluid outlet header **112** is seen to include openings **118** such that fluid to be cooled, heated, evaporated or condensed may exit from within each plate pair **116**. Further passageways **120** are shown between plates **116** such that evaporative liquid and air can pass on the outside of plates **116** to provide both sensible and latent heat transfer to the fluid passing within joined plate or cassettes **116** of plate heat exchanger **110**. Each plate cassette **116** is seen to include an internal fluid passageway **122** that allows fluid to be cooled, heated, condensed, or evaporated to enter through fluid inlet header **114**, pass through the interior of joined plate pairs or cassettes **116** and exit through openings **118** in each plate pair to enter outlet header **112**. Such plate heat exchanger assembly **110** is seen to include usually a Chevron, embossing, cross hatch, dimpled, micro structurally extended, or any other surface enhancement pattern on both sides of each cassette assembly **116** to provide increased surface area and turbulent flow to allow improved performance and heat exchange between the fluid within the each cassette **116** and the air and evaporative liquid passing on the outside surface of each cassette **116**. The geometries of the surface enhancement pattern on the plate are strategically selected such that the passageway formed in the space between each cassette assembly **116** allows good heat and mass transfer between the air and the evaporative liquid which pass concurrently between each cassette **116**. This external passageway is usually, but not limited to, a general criss-cross pattern formed as the chevron patterns from adjacent cassettes approach close to, or even contacting, each other. Such arrangement leads to the overall improved performance in all the embodiments of the heat exchanger of the present invention that include an indirect heat exchange section. The surface pattern could be different on each side of the plate. The plate surface could be chemically treated (i.e., nano spray coated) to achieve an optimized surface tension value and thus enhance the air and evaporative liquid interaction.

Referring now to FIG. **13**, a plate heat exchanger in accordance with the present invention is shown generally at **130**. Each such plate heat exchanger is seen to be comprised of a series of adjacent plate pairs or cassettes **136**. Each plate cassette **136** has an internal spacing within to allow a fluid to enter through fluid inlet header **134** pass within each plate cassette **136** and exit through fluid outlet header **132**. Each inlet header includes a spacer ring **134**A to allow header **134** to be affixed to the series of plate cassettes **136**, and an outlet header spacer ring **132**A to allow fluid outlet header **132** to be attached to the series of plate cassettes **136**. Further, spacing **138** is seen in an exploded arrangement to exist between each plate cassette **136** to provide an adequate passageway for evaporative liquid to pass in a cross-current, parallel-current, counter-current or some combination thereof arrangement with assembled plates **136**. Such spacing also allows for air to pass between such plates such air usually being drawn in a cross-current, counter-current, parallel-current fashion or some combination thereof arrangement by fans within the heat exchanger. Such spacing between plate cassettes allows for increased performance of the indirect heat exchange section comprised of plate heat exchanger **130** by allowing both sensible and latent heat exchange to occur between the fluid within each plate pair or cassette **136** and the evaporative liquid and air passing in the passageway between such plate pair or cassettes **136**. The internal passage within each plate cassette is labeled **139**.

Referring now to FIG. **14**, a perspective view of a plate heat exchanger assembly **140** is shown. Plate heat exchanger assembly **140** is seen to be comprised of a series of plate cassettes **146** each of which includes an internal passageway to allow fluid to pass therein. Each plate cassette is seen to ideally be comprised of a chevron or other surface arrangement to provide increased surface area of each plate pair. Plate heat exchanger assembly **140** is seen to also comprise a fluid outlet header **142** connected to the series of plate cassettes by outlet header spacer ring **142**A, and a fluid inlet header **144** connected to the series of plate cassettes **146** by inlet header spacer ring **144**A. Passageway **148** is seen to be created by the extended surface on the outside of each neighboring plate cassette **146** such that an evaporative liquid can be allowed to pass between each plate cassette **146** to provide sensible cooling for the liquid passing within each plate cassette **146**. Further, passageway **148** provides space between plate cassettes **146** such that air can be drawn in a counter-current, parallel-current, cross-current fashion, or some combination thereof arrangement between plate cassettes **146** to also provide both sensible and latent heat exchange with the evaporative liquid, and hence provide indirect cooling, heating, condensing, or evaporating for the fluid within plates **146**. The spacers, **149**, are optional which provide extra structure support to the plate heat exchanger assembly **140** to prevent the extended surface from crushing when the plate heat exchanger assembly **140** is tightened by bolts. Also, the spacers **149** may be used to increase the width of the passageway **148** beyond its natural value which is two times of the height of the extended surface.

Referring now to FIGS. **15-18**, a detailed view of plate heat exchanger assembly **150** is shown. Each plate heat exchanger assembly is seen to be comprised of a series of plate pairs or cassettes **156** with a fluid outlet header **152** and a fluid inlet header **154**. Each fluid inlet header **154** is connected by a fluid inlet header space ring **154**A and fluid outlet header **152** is seen to be connected by a fluid outlet header space ring **152**A. The series of plate pairs or cassettes **156** are seen to be spaced from each other by the extended surface pattern on the outside of each plate cassette **156**. On each plate, the enhanced surface pattern is on both sides. It is composed of extended surfaces (peaks, **158**A) and downwardly extruded surfaces (valleys, **158**B). The peaks **158**A on one side of the plate is the valleys **158**B on the other side (and vice versa). The valleys **158**B touch each other to form the internal passageways **159** within the plate pair or cassette **156**. The peaks **158**A on the outside surface of each plate pair **156** touch the peaks of the neighboring plate pair **156** to form the external passageway **158** (e.g., typically a criss-cross pattern) such that air and evaporative liquid can pass outside and between plate cassettes **156** to provide both good sensible and latent heat exchanges. Each plate cassette **156** is seen to usually have a Chevron or any other surface enhancement pattern on both sides of each cassette assembly **156** to provide increased surface area and turbulent flow to allow improved performance and heat exchange between the fluid within the each cassette **156** and the evaporative liquid passing between each cassette **156**. The geometries of the surface enhancement pattern on the plate are strategically selected such that the external passageways **158** formed in the space between each cassette assembly **156** allows good heat and mass transfer between the air and the evaporative liquid which pass concurrently outside and between each cassette **156**. This external passageway is usually, but not limited to, a general criss-cross pattern.

In all the embodiments of the present invention, the plates can be comprised of various steels such as stainless steel or other corrosion resistant steels and alloys. It is also possible that such plates can be comprised of other materials that would lead to good heat exchange between the fluid within the plate and the evaporative liquid or air passing outwardly therefrom. Such materials could be aluminum or copper; various alloys, or plastics that provide corrosion resistance and good heat exchange.

What is claimed is:

1. A method of exchanging heat comprising the steps of:

providing a direct evaporative heat exchange section and an indirect heat exchange section,

the indirect heat exchange section conducting a fluid stream within a plurality of pathways,

the direct heat exchange section comprising a top, a bottom, an air inlet, and an air outlet,

the indirect heat exchange section comprising a top, a bottom, an air inlet and an air outlet,

the indirect heat exchange section being placed generally above the direct heat exchange section,

distributing an evaporative liquid generally downward onto and through the indirect heat exchange section such that indirect heat exchange occurs between the fluid stream within the plurality of pathways and the evaporative liquid,

moving air between the air inlet and the air outlet of the indirect section, and

moving air between the air inlet and the air outlet of the direct section,

the air moving through the indirect heat exchange section exchanging both heat and mass with the evaporative liquid moving through the indirect heat exchange section and hence indirectly exchanging heat with the fluid stream within the plurality of pathways in the indirect section,

the air moving through the direct heat exchange section exchanging heat and mass with the evaporative liquid moving through the direct heat exchange section,

distributing substantially all of the evaporative liquid leaving the indirect heat exchange section generally downward onto the direct heat exchange section,

wherein the indirect heat exchange section is comprised of a plate type heat exchanger,

the plate type heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of first series of flow passages and a second series of flow passages,

an inlet header and an outlet header operatively connected to the first series of flow passages such that the fluid stream can pass into the first series of flow passages and out from the first series of flow passages,

the second series of flow passages arranged such that the evaporative liquid can pass through the second series of flow passages and such that the air moving through the indirect section passes through the second series of flow passages.

2. The method of exchanging heat of claim **1**, further comprising:

collecting substantially all of the evaporative liquid that exits the direct heat exchange section, and

pumping the collected evaporative liquid upwardly such that it can be distributed generally downward onto and through the indirect heat exchange section.

3. The method of exchanging heat of claim **1**, wherein the air moving through the indirect heat exchange section moves generally counter-current to the direction of flow of the evaporative liquid through the indirect heat exchange section.

4. The method of exchanging heat of claim **1**, wherein the air moving through the indirect heat exchange section moves generally cross-current to the direction of flow of the evaporative liquid through the indirect heat exchange section.

5. The method of exchanging heat of claim **1**, wherein the air moving through the direct heat exchange section moves generally cross-current to the direction of flow of the evaporative liquid through the direct heat exchange section.

6. The method of exchanging heat of claim **1**, wherein in the plate type heat exchanger comprised of a series of adjacent plate cassettes

forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

each plate cassette in the series of adjacent plate cassettes includes an enhanced surface pattern to increase plate surface area, to increase the sensible heat transfer from the fluid stream within the closed loop first series of flow passages to the evaporative liquid, and to increase the sensible and latent heat transfer from the evaporative liquid to the air moving through the second series of flow passages in the plate type heat exchanger.

7. The method of exchanging heat of claim **1**, wherein in the plate type heat exchange comprised of a series of adjacent plate cassettes

forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

a second inlet header and a second outlet header are operatively connected to a third series of closed loop flow passages in the plate heat exchanger such that a second fluid stream can pass into the third series of flow passages and out from the third series of flow passages.

8. The method of exchanging heat of claim **1** wherein two direct heat exchange sections and two indirect heat exchange sections are provided, with one indirect heat exchange section located generally above one direct heat exchange section, with the second indirect heat exchange section located generally above the second direct heat exchange section.

9. The method of exchanging heat of claim **1**, wherein two direct heat exchange sections are provided, with the indirect heat exchange section located generally above both direct heat exchange sections.

10. The method of exchanging heat of claim **1**, wherein the air moving through the indirect heat exchange section moves generally parallel-current to the direction of flow of the evaporative liquid through the indirect heat exchange section.

11. The method of exchanging heat of claim **1** wherein the air moving through the direct heat exchange section moves generally counter-current to the direction of flow of the evaporative liquid through the direct heat exchange section.

12. A method of exchanging heat comprising the steps of:

providing a direct evaporative heat exchange section and an indirect heat exchange section,

the indirect heat exchange section conducting a fluid stream within a plurality of pathways,

the direct heat exchange section comprising a top, a bottom, an air inlet, and an air outlet,

the indirect heat exchange section comprising a top, a bottom, an air inlet and an air outlet,

the indirect heat exchange section being placed generally above the direct heat exchange section,

moving air between the air inlet and the air outlet of the indirect section, and moving air between the air inlet and the air outlet of the direct section,

the air moving through the indirect heat exchange section exchanging heat with the fluid stream within the plurality of pathways in the indirect section,

wherein the indirect heat exchange section is comprised of a plate type heat exchange assembly,

the plate type heat exchange assembly comprised of a series of adjacent plate cassettes

forming an alternating arrangement of a first series of flow passages and a second series of flow passages,

an inlet header and

an outlet header operatively connected to the first series of flow passages such that the fluid stream can pass into the first series of flow passages and out from the first series of flow passages,

the second series of flow passages arranged such that the air moving through the indirect section passes through the second series of flow passages.

13. The method of exchanging heat of claim **12**, wherein the air moving through the indirect heat exchange section moves generally counter-current to the direction of flow of the fluid stream through the indirect heat exchange section.

14. The method of exchanging heat of claim **12**, wherein the air moving through the indirect heat exchange section moves generally cross-current to the direction of flow of the fluid stream.

15. The method of exchanging heat of claim **12**, wherein the air moving through the indirect heat exchange section moves generally parallel-current to the direction of flow of the fluid stream.

16. The method of exchanging heat of claim **12**, wherein the plate type heat exchange assembly comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

each plate cassette in the series of adjacent plate cassettes includes an enhanced surface pattern to increase plate surface area and to increase the heat transfer from the fluid stream to the air moving through the second series of open loop flow passages in the plate type heat exchange assembly.

17. The method of exchanging heat of claim **12** wherein the plate type heat exchange assembly comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

a second inlet header and a second outlet header are operatively connected to a third series of closed loop flow passages in the plate heat exchanger such that a second fluid stream can pass into the third series of flow passages and out from the third series of flow passages.

18. The method of exchanging heat of claim **12** wherein two direct heat exchange sections and

two indirect heat exchange sections are provided, with one indirect heat exchange section located generally above one direct heat exchange section and the second indirect heat exchange section located generally above the second direct heat exchange section.

19. The method of exchanging heat of claim **12**, wherein two direct heat exchange sections are provided, and

the indirect heat exchange section located generally above both direct heat exchange sections.

20. A method of exchanging heat comprising the steps of:

providing an indirect heat exchange section,

the indirect heat exchange section conducting a fluid stream within a plurality of pathways,

the indirect heat exchange section comprising a top, a bottom, an air inlet and an air outlet,

distributing an evaporative liquid generally downward onto and through the indirect heat exchange section such that indirect heat exchange occurs between the fluid stream within the plurality of pathways and the evaporative liquid,

moving air between the air inlet and the air outlet of the indirect heat exchange section,

the air moving through the indirect heat exchange sections exchanging heat and mass with the evaporative liquid moving through the indirect heat exchange section and hence indirectly exchanging heat with the fluid stream within the plurality of pathways in the indirection section,

wherein the indirect heat exchange section is comprised of a plate heat exchanger,

the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of flow passages and

a second series of flow passages,

an inlet header and

an outlet header operatively connected to the first series of flow passages such that the fluid stream can pass into the first series of flow passages and out from the first series of flow passages,

the second series of flow passages arranged such that the evaporative liquid can pass through the second series of flow passages and such that the air moving through the indirect section passes through the second series of flow passages, wherein

the air moving through the indirect heat exchange section moves counter-current to the direction of flow of the evaporative liquid through the indirect heat exchange section.

21. The method of exchanging heat of claim **20**, further comprising:

collecting substantially all of the evaporative liquid that exits the indirect heat exchange section, and

pumping the collected evaporative liquid upwardly such that it can be distributed generally downwardly onto and through the indirect heat exchange section.

22. The method of exchanging heat of claim **20** wherein the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

each plate cassette in the series of adjacent plate cassettes includes an enhanced surface pattern to increase plate surface area and to increase the sensible and latent heat transfer from the evaporative liquid to the air moving through the second series of flow passages in the plate heat exchanger.

23. The method of exchanging heat of claim **20** wherein in the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

a second inlet header and a second outlet header are operatively connected to a third series of closed loop flow passages in the plate heat exchanger such that a second fluid stream can pass into the third series of closed loop flow passages and out from the third series of flow passages.

24. The method of exchanging heat of claim **20** wherein the air moving through the indirect heat exchange section moves generally parallel-current to the direction of evaporative liquid through the indirect heat exchange section.

25. A method of exchanging heat comprising the steps of:

providing an indirect heat exchange section,

the indirect heat exchange section conducting a fluid stream within a plurality of pathways,

the indirect heat exchange section comprising a top, a bottom, an air inlet and an air outlet,

distributing an evaporative liquid generally downward onto and through the indirect heat exchange section such that indirect heat exchange occurs between the fluid stream within the plurality of pathways and the evaporative liquid,

moving air between the air inlet and the air outlet of the indirect heat exchange section,

the air moving through the indirect heat exchange sections exchanging heat and mass with the evaporative liquid moving through the indirect heat exchange section and hence indirectly exchanging heat with the fluid stream within the plurality of pathways in the indirection section,

wherein the indirect heat exchange section is comprised of a plate heat exchanger,

the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of flow passages and

a second series of flow passages,

an inlet header and

an outlet header operatively connected to the first series of flow passages such that the fluid stream can pass into the first series of flow passages and out from the first series of flow passages,

the second series of flow passages arranged such that the evaporative liquid can pass through the second series of flow passages and such that the air moving through the indirect section passes through the second series of flow passages, wherein

in the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

a second inlet header and a second outlet header are operatively connected to a third series of closed loop flow passages in the plate heat exchanger such that a second fluid stream can pass into the third series of closed loop flow passages and out from the third series of flow passages.

26. The method of exchanging heat of claim **25**, further comprising:

collecting substantially all of the evaporative liquid that exits the indirect heat exchange section, and

pumping the collected evaporative liquid upwardly such that it can be distributed generally downwardly onto and through the indirect heat exchange section.

27. The method of exchanging heat of claim **25**, wherein the air moving through the indirect heat exchange section moves counter-current to the direction of flow of the evaporative liquid through the indirect heat exchange section.

28. The method of exchanging heat of claim **25** wherein the air moving through the indirect heat exchange section moves generally cross-current to the direction of flow of the evaporative liquid, through the indirect heat exchange section.

29. The method of exchanging heat of claim **25**, wherein the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

each plate cassette in the series of adjacent plate cassettes includes an enhanced surface pattern to increase plate surface area and to increase the sensible and latent heat transfer from the evaporative liquid to the air moving through the second series of flow passages in the plate heat exchanger.

30. The method of exchanging heat of claim **25** wherein the air moving through the indirect heat exchange section moves generally parallel-current to the direction of evaporative liquid through the indirect heat exchange section.

31. A method of exchanging heat comprising the steps of:

providing an indirect heat exchange section,

the indirect heat exchange section conducting a fluid stream within a plurality of pathways,

the indirect heat exchange section comprising a top, a bottom, an air inlet and an air outlet,

distributing an evaporative liquid generally downward onto and through the indirect heat exchange section such that indirect heat exchange occurs between the fluid stream within the plurality of pathways and the evaporative liquid,

moving air between the air inlet and the air outlet of the indirect heat exchange section,

the air moving through the indirect heat exchange sections exchanging heat and mass with the evaporative liquid moving through the indirect heat exchange section and hence indirectly exchanging heat with the fluid stream within the plurality of pathways in the indirection section,

wherein the indirect heat exchange section is comprised of a plate heat exchanger,

the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of flow passages and a second series of flow passages,

an inlet header and

an outlet header operatively connected to the first series of flow passages such that the fluid stream can pass into the first series of flow passages and out from the first series of flow passages,

the second series of flow passages arranged such that the evaporative liquid can pass through the second series of flow passages and such that the air moving through the indirect section passes through the second series of flow passages, wherein the air moving through the indirect heat exchange section moves generally parallel-current to the direction of evaporative liquid through the indirect heat exchange section.

32. The method of exchanging heat of claim **31**, further comprising:

collecting substantially all of the evaporative liquid that exits the indirect heat exchange section, and

pumping the collected evaporative liquid upwardly such that it can be distributed generally downwardly onto and through the indirect heat exchange section.

33. The method of exchanging heat of claim **31**, wherein the air moving through the indirect heat exchange section moves counter-current to the direction of flow of the evaporative liquid through the indirect heat exchange section.

34. The method of exchanging heat of claim **31** wherein the air moving through the indirect heat exchange section moves generally cross-current to the direction of flow of the evaporative liquid, through the indirect heat exchange section.

35. The method of exchanging heat of claim **31** wherein the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

each plate cassette in the series of adjacent plate cassettes includes an enhanced surface pattern to increase plate surface area and to increase the sensible and latent heat transfer from the evaporative liquid to the air moving through the second series of flow passages in the plate heat exchanger.

36. The method of exchanging heat of claim **31** wherein in the plate heat exchanger comprised of a series of adjacent plate cassettes forming an alternating arrangement of a first series of closed loop flow passages and

a second series of open loop flow passages,

a second inlet header and a second outlet header are operatively connected to a third series of closed loop flow passages in the plate heat exchanger such that a second fluid stream can pass into the third series of closed loop flow passages and out from the third series of flow passages.

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